Irish Journal of Agricultural and Food Research **44:** 57–67, 2005

The effect of dietary garlic and rosemary on grower-finisher pig performance and sensory characteristics of pork

S.P. Cullen, F.J. Monahan, J.J. Callan and J.V. O'Doherty†

School of Agriculture, Food Science and Veterinary Medicine, College of Life Sciences, University College Dublin, Belfield, Dublin 4

The objective of this study was to investigate the effects of inclusion of rosemary (*Rosmarinus officinalis*) and garlic (*Allium sativum*) in pig diets on apparent nutrient digestibility, pig performance, carcass characteristics and on sensory characteristics of the pork. Seventy individually-fed grower-finisher pigs (42 kg live weight) were offered one of the following diets *ad-libitum:* (1) control diet (based on wheat, pollard and soyabean meal), (2) control diet supplemented with rosemary at 1 g/kg (low rosemary; LR), (3) control diet supplemented with rosemary at 10 g/kg (high rosemary; HR), (4) control diet supplemented with garlic at 1 g/kg (low garlic; LG) and (5) control diet supplemented with garlic at 10 g/kg (high garlic; HG). Pigs offered diets with garlic had a lower feed intake ($P < 0.01$) and lower digestible energy intake ($P < 0.05$) compared to the pigs offered the control or rosemary diets during the grower-finisher period. Pigs offered the LG and HG diets had a better ($P < 0.05$) food conversion ratio (FCR) than the pigs offered the control or rosemary diets. Digestibility of dry matter and organic matter were lower ($P < 0.05$) for the HG diet than the LG diet. Gross energy digestibility and digestible energy concentration were lower for the HR than the LR diet. Sensory panellists found a significant difference ($P < 0.001$) in the sensory properties of cooked muscle from the control and HG treatments. In conclusion, the addition of garlic to the diets of grower-finisher pigs reduced feed intake and improved FCR while the addition of rosemary had no beneficial effects on growth performance or carcass characteristics.

Keywords: Carcass and sensory characteristics; garlic; pig diets; rosemary

†Corresponding author: john.vodoherty@ucd.ie

Introduction

There is increased concern over the use of antibiotics as growth promoters in animal feeds (Close, 2000). As a result, attention is being focussed on setting new regulations for more natural production methods that are friendly to animals, the consumer and the environment (Wenk, 2000). One area receiving increasing attention is herbs and herb mixtures (McDonald and Wood, 2002). Although a wide range of herbs, spices and oils are available for inclusion in animal feeds, one that is receiving a great deal of attention is garlic. Garlic (*Allium sativum*) contains an active compound known as allicin, which was identified by Cavallito and Bailey (1944) as the agent responsible for garlic's potent antibacterial properties. Allicin was found to be effective against a number of gram-positive and gram-negative bacteria (Cavallito and Bailey, 1944), as well as being antifungal (Small, Bailey and Cavallito, 1947) and antiviral (Tsai *et al.,* 1985). In addition to its antimicrobial activities, garlic has been shown to increase feed palatability and thus feed intake (Horton, Blethen and Prasad, 1991).

Natural antioxidants are also receiving increased attention in human and animal nutrition because of their association with food quality characteristics and immune response (Lin *et al.,* 1989; Ashgar *et al.,* 1989). Some spices and herbs, including rosemary (*Rosmarinus officinalis*), contain compounds that have been reported to have antioxidant properties (Farag *et al.,* 1989; Liu *et al.,* 1992).

Because of the antimicrobial, antioxidant and flavour enhancing properties of garlic and rosemary, these herbs may promote growth and feed utilisation in post weaned piglets (Jost, 1996). However, this area of research has not received substantial examination because of the relatively low costs, proven effectiveness and ready availability of synthetic growth-promoting antibacterial products. The potential beneficial effects of both garlic and rosemary on the growth performance of grower-finisher pigs need to be clarified. The objectives of this study were to determine (i) the apparent total-tract nutrient digestibility of diets supplemented with two levels of rosemary (*Rosmarinus officinalis*) or two levels of garlic (*Allium sativum*) and (ii) the growth performance, carcass characteristics and sensory quality of the pork of grower-finisher pigs fed such diets.

Materials and Methods

Experimental diets

The experiment involved five treatments during the grower-finisher period: (1) control diet (based on wheat, soyabean meal and pollard; Table 1), (2) control diet supplemented with freeze-dried rosemary (Gerald McDonald & Co. Ltd., Cranes Farm Road, Basildon, Essex SS14 3GT, UK) at 1 g/kg (low rosemary, LR), (3) control diet supplemented with rosemary at 10 g/kg (high rosemary, HR), (4) control diet supplemented with dried garlic (Interprise Ltd., Aberfen Road, Baglan Bay Ind. Estate, Port Talbot, West Glamorgan SA12 7DJ, Wales) at 1 g/kg (low garlic, LG) and (5) control diet supplemented with garlic at 10 g/kg (high garlic, HG). The diets were formulated, using standard feeding values for the ingredients (R & H Hall, Technical Bulletin, 1996), so as to have identical levels of digestible energy (DE) (13.8 MJ/kg) and lysine (11.5 g/kg). All diets were supplemented with 150 mg/kg of chromic oxide. The chemical composition of the diets is presented in Table 2.

Animals and management

Seventy entire male Large White × (Large White × Landrace) pigs were used in the

Table 1. Composition of the control diet

Ingredient	Inclusion rate (g/kg)
Wheat	600
Soyabean meal	320
Pollard	50
Soya oil	10
Mineral and vitamin premix[1]	20

[1]The vitamin and mineral pre-mix supplied the following per kg food: 2 mg retinol, 0.05 mg cholecalciferol, 40 mg α-tocopherol, 4 mg phytylmenaquinone, 2 mg riboflavin, 10 mg D-pantothenic acid, 12 mg nicotinic acid, 50 mg ascorbic acid, 15 g cyanocobalamin, 3 mg pyridoxine, 2 mg thiamin, 400 mg copper as sulphate, 200 mg iron as sulphate, 40 mg manganese as oxide, 100 mg zinc as oxide and 0.4 mg of sodium selenite, 150 mg chromic oxide.

experiment. They were approximately 13 weeks of age and had an initial mean live weight of 42 kg (s.d. 1.2 kg). Previously the pigs received standard commercial feeding and management. The pigs were blocked on the basis of live weight and pigs in each block were allocated at random to one of the five dietary treatments. The pigs were penned in groups of six with a space allowance of 0.75 m^2 per pig and were allowed into individual feeding crates at feeding time. The pens consisted of a 70:30 solid:slatted floor area. The house was mechanically ventilated to provide an ambient temperature of 18 °C. Water was available *ad libitum* from nipple drinkers. The pigs were allowed 7 days to become familiar with the individual feeding crates and wet feeding. The pigs were fed twice daily on a scale ranging from 1.5 kg per day at 42 kg live weight to *ad-libitum* feed for 1 h in the morning and evening. The individual feeding troughs were checked daily after the evening feed. If the pig had consumed all its allocated feed, the feed allowance was increased by 100 g per pig for the following day up to *ad-libitum* feed intake. The feed was presented as a

Table 2. Chemical composition (g/kg fresh weight) of the experimental diets

Component	Treatment[1]				
	Control	LR	HR	LG	HG
Dry matter	866	871	874	869	876
Ash	42	41	41	42	42
Neutral detergent fibre	122	121	133	132	136
Crude protein	202	204	205	203	209
Crude fibre	32	29	30	28	31
Ether extract	22	23	21	21	23
Gross energy (MJ/kg)	15.9	16.0	16.0	15.9	16.0
Calcium	7.0	7.0	7.0	7.0	7.0
Phosphorus	5.5	5.5	5.5	5.5	5.5
Lysine	11.5	11.5	11.5	11.5	11.5
Methionine and cystine	7.3	7.3	7.3	7.3	7.3
Threonine	8.1	8.1	8.1	8.1	8.1
Tryptophan	2.2	2.2	2.2	2.2	2.2

[1]Control = diet specified in Table 1; LR = control diet supplemented with rosemary at 1 g/kg; HR = control diet supplemented with rosemary at 10 g/kg; LG = control diet supplemented with garlic at 1 g/kg; HG = control diet supplemented with garlic at 10 g/kg.

meal mixed with water in the proportion 1:2 w/v. Throughout the experiment representative samples of the diets were taken at the time of feeding and retained at 4 °C in an airtight container until required for chemical analysis. Following 4 weeks on the experimental diets, daily grab samples of fresh faeces were taken on three consecutive days from five pigs per treatment for chromium analysis. Grab samples were taken from the same pig on each occasion. The pigs were weighed individually at the onset of the experiment (day 0), at day 28 (end of grower phase) and at day 56 (end of finisher phase).

Carcass analysis

The pigs were slaughtered at a commercial slaughtering facility (Glanbia Meats, Edenderry, Co. Offaly) at the end of the finisher phase in one batch. Within 1 h of slaughter, the warm carcass was weighed and subcutaneous backfat and eye muscle depth measurements were taken 6.5 cm from the midline of the split back between the 3rd and 4th last ribs using a Hennessy grading probe (HGP, Hennessey and Chong, Auckland, New Zealand). Lean meat proportion was estimated from the backfat and eye muscle depth measurements using the equation (Department of Agriculture and Food, 1994):

Lean meat proportion (g/kg carcass) = 534.1 – 7.86 probe fat (mm) + 2.66 muscle depth (mm).

Meat sampling

Following overnight chilling 35 carcasses (7 from each treatment) were randomly selected for sampling and a 10-cm sample of the *longismus dorsi* (LD) muscle was taken from each carcass. The samples were taken to the laboratory where each sample was divided into four steaks which were individually vacuum-packed and placed in storage at –20 °C until analysed.

Laboratory analyses

The dry matter concentrations of the feeds and faeces were determined by oven drying at 55 °C for 72 h with forced air circulation. The dried concentrates and faeces were milled through a 1-mm screen (Christy and Norris hammer mill, Christy and Norris, Scunthorpe, UK). The gross energy of the feed and faecal samples was measured using a bomb calorimeter (Parr Instrument Company, IL, USA). Samples were analysed for ash by burning in a furnace at 600 °C for 4 h; for crude protein by the macro-Kjeldahl method (Kjeldahl N × 6.25) (AOAC, 1980), for neutral detergent fibre content by the method of Van Soest, Robertson and Lewis (1991) and for crude fibre by the Weende method (AOAC, 1980). Ether extract was determined using the 1043 Soxtec System HT6 as derived from the Soxhlet method (AOAC, 1980). The chromium concentration was determined according to the method of Williams, David and Iismaa (1962). The alliin and allicin concentrations of the garlic were determined using the methods of Ziegler and Sticher (1989) and Arnault *et al.* (2003), respectively.

Sensory analysis

A triangle test (Meilgaard, Civilla and Carr, 1999) was carried out to determine whether or not panellists could differentiate between pork from pigs fed the control diet and pork from pigs fed each of the herb-supplemented diets. Twenty-six untrained panellists took part in the sensory analysis. For each dietary treatment, LD from the seven carcasses was trimmed of extramuscular fat, ground, combined and mixed thoroughly. The ground muscle was divided into 80 g patties (16 cm × 8 cm) each of which was vacuum packed and stored at –20 °C for 24 h prior to cooking. Immediately prior to the sensory analysis session, each patty was removed from the vacuum pack, wrapped in aluminium foil and baked in a conventional oven set at 100 °C for 35 min. An internal temperature of 80 °C, monitored using a thermocouple (Digitron Instrumentation Thermometer Ltd., Mead Lane, Hertford, Herts, England) was reached within 25 min. Immediately after cooking each patty was divided into 12 similarly sized pieces and each piece was labelled with a random 3-digit number. Each panellist was presented with three samples of cooked pork (two identical, one different) and asked to record the number of the odd sample on the sensory sheet provided. All testing sessions were conducted in a sensory analysis laboratory equipped with individual testing booths and controlled lighting (Meilgaard *et al.,* 1999). The four comparisons (control *v.* LG, control *v.* HG, control *v.* LR, control *v.* HR) were undertaken on different days and on each day the sensory analysis took place in four sessions with seven panellists per session.

Statistical analysis

For both performance and digestibility, the data were analysed using Proc GLM of SAS (1985). Pig performance data were adjusted for pig live weight at the beginning of the experiment by covariance. Values for kill-out, back fat depth and lean meat proportion were adjusted for slaughter weight by covariance. The results are presented as least square means (LSM) with associated s.e. Contrast statements were used to evaluate the following *a priori* comparisons; control diet *v.* rosemary (LR and HR), control diet *v.* garlic (LG and HG), garlic *v.* rosemary, 10 g/kg rosemary *v.* 1 g/kg rosemary and 10 g/kg garlic *v.* 1 g/kg garlic. The sensory analysis results were analysed as described in Meilgaard *et al.* (1999).

Results

The alliin concentration of the garlic supplement was 19 mg/g while the allicin concentration was 7 mg/g.

Pig performance

The effects of dietary treatment on feed intake, daily live-weight gain, feed conversion ratio (FCR), digestible energy (DE) intake and DE conversion ratio are presented in Table 3. There was no significant difference in daily live-weight gain between any of the treatments during the grower, finisher or combined grower- finisher periods.

Pigs offered the garlic diets (LG and HG) had a lower ($P < 0.01$) feed intake and digestible energy (DE) intake than the control or rosemary (LR and HR) diets during the grower and combined grower-finisher period. During the finisher period, pigs offered the garlic diets had a lower ($P < 0.001$) feed intake than the pigs offered the rosemary diets. The intake of pigs offered the rosemary diets was higher ($P < 0.05$) than the control during the finisher period.

Pigs offered the garlic diets had a better ($P < 0.05$) FCR than pigs offered the control or rosemary diets during the grower and during the combined grower-finisher periods but there was no significant difference in FCR during the finisher period. Pigs offered the garlic diets had a better ($P < 0.05$) digestible energy conversion ratio than the control and rosemary diets during the grower-finisher period.

The effects of dietary treatment on carcass characteristics are presented in Table 4. Pigs offered the garlic diets had a better ($P < 0.05$) carcass FCR than the pigs offered the control or rosemary diets.

Diet digestibility

The effect of dietary treatment on the apparent nutrient digestibility is presented in Table 5. The digestibility of dry matter,

Table 3. Effect of dietary treatment on pig performance

Variable	Treatment[1]					s.e.	Significance of contrasts[2]		
	Control	LR	HR	LG	HG		C1	C2	C3
Grower phase (weeks 0 to 4)									
Weight at start (kg)	42.2	42.6	43.1	42.5	41.6	–			
Weight at week 4 (kg)	67.4	68.7	66.8	68.2	66.7	0.93			
Feed intake (kg/day)	2.12	2.12	2.01	1.93	1.86	0.054		**	**
Digestible energy (DE) intake (MJ/day)	30.5	30.6	28.3	27.7	26.5	0.780		**	**
Daily gain (kg/day)	1.00	1.01	0.92	1.00	0.95	0.039			
Food conversion ratio (kg/kg)	2.15	2.12	2.26	1.94	2.00	0.083		*	*
DE conversion ratio (MJ/kg)	30.8	30.6	31.9	27.8	28.5	1.18			
Finisher phase (weeks 5 to 8)									
Feed intake (kg/day)	2.50	2.57	2.64	2.46	2.43	0.043	*		***
DE intake (MJ/day)	36.0	36.8	37.3	35.3	34.5	0.68			
Daily gain (kg/day)	0.91	0.94	0.99	0.92	0.93	0.033			
Food conversion ratio (kg/kg)	2.80	2.76	2.69	2.74	2.65	0.095			
DE conversion ratio (MJ/kg)	40.2	43.4	38.1	41.4	37.5	2.28			
Weight at week 8 (kg)	92.8	95.0	94.5	94.0	92.9	1.55			
Grower-finisher period (weeks 0 to 8)									
Feed intake (kg/day)	2.32	2.36	2.34	2.20	2.16	0.038		**	**
DE intake (MJ/day)	33.3	33.8	32.9	31.6	30.7	0.55		**	*
Daily gain (kg/day)	0.95	0.97	0.96	0.95	0.94	0.023			
Food conversion ratio (kg/kg)	2.47	2.44	2.47	2.33	2.31	0.062		*	*
DE conversion ratio (MJ/kg)	35.4	36.1	34.9	34.0	32.8	0.96		*	*

[1]See footnote to Table 2 for definitions.
[2]C1 = difference between control and (LR + HR)/2; C2 = difference between control and (LG + HG)/2; C3 = difference between LG + HG and LR + HR.

Table 4. Effect of dietary treatment on pig carcass characteristics

Variable	Treatment[1]					s.e.	Significance of contrasts[2]		
	Control	LR	HR	LG	HG		C1	C2	C3
Weight at slaughter (kg)	92.8	95.0	94.5	93.9	92.8	1.55			
Carcass weight (kg)	67.2	67.2	67.1	67.1	68.2	0.48			
Kill-out proportion (g/kg)	717	719	718	717	730	5.0			
Back fat depth (mm)	11.1	10.8	12.8	10.8	11.0	0.66			
Lean yield (g/kg)	579	582	559	582	580	7.7			
Carcass gain (kg/day)	0.72	0.75	0.74	0.74	0.75	0.02			
Carcass feed conversion ratio (kg/kg)	3.3	3.3	3.3	3.2	3.0	0.10		*	*

[1]See footnote to Table 2 for definitions.
[2]See footnote to Table 3.

organic matter and gross energy were lower ($P < 0.05$) for the HG diet than the LG diet. The inclusion of rosemary resulted in a reduction in ash digestibility compared to the control diet ($P < 0.05$) and the garlic diets ($P < 0.001$). Gross energy (GE) digestibility and DE concentration were lower for the HR diet than for the LR diet ($P < 0.05$).

Sensory analysis

Panellists found a significant difference ($P < 0.001$) between the sensory properties of cooked pork from the control and HG diets (Table 6). Panellists were unable to differentiate between cooked muscle from the control group and the LR or HR groups.

Discussion

There were no beneficial effects on nutrient digestibility of the diets following the inclusion of garlic or rosemary. No previous research has been found in the literature regarding the effects of rosemary on nutrient digestibility. However, the reduced nutrient digestibility in the present study, following the inclusion of the higher level of rosemary may be due to the presence of tannins (Inatani, Nakatani and Fuwa, 1983; Cuvelier, Richard and Bersert, 1996) in rosemary. Tannins form complexes with proteins and carbohydrates in the feed, and can hinder the production of digestive enzymes, therefore causing a depression in nutrient digestibility (Jansman, 1993; Yu *et al.,* 1996). It has also been shown by Griffiths and Moseley (1980) that rats on high-tannin diets had reduced activities of the digestive enzymes, trypsin, chymotrypsin and α-amylase.

The inclusion of garlic at the higher level caused a significant reduction in dry matter and organic matter digestibilities in addition to showing a trend ($P=0.13$) towards reduced digestibility of nitrogen. There may be a number of reasons for this. Firstly garlic may be classified as a fructooligosaccharide due to its high oligofructose and inulin content (Gibson, 2001). Negative effects of increased dietary non-starch polysaccharide (NSP) levels on the digestibility of starch, proteins and fat have been demonstrated (Fernandez and Jorgensen, 1986). Soluble NSP may stimulate microbial growth and increase the amount of microbial protein and fat at the terminal ileum and in the faeces. Viscous NSP can interfere with digesta movement and the mixing of digestive enzymes and

Table 5. Effect of dietary treatment on apparent nutrient digestibility and digestible energy concentration

	Treatment[1]					s.e.	Significance of contrasts[2]				
	Control	LR	HR	LG	HG		C1	C2	C3	C4	C5
Digestibility (kg/kg) of											
Dry matter	0.903	0.901	0.889	0.904	0.888	0.005					*
Organic matter	0.915	0.915	0.902	0.915	0.899	0.002					*
Nitrogen	0.899	0.898	0.884	0.897	0.882	0.008					
Ash	0.663	0.626	0.627	0.695	0.666	0.011	*		***		
Neutral detergent fibre	0.684	0.696	0.667	0.697	0.669	0.027					
Gross energy	0.900	0.902	0.885	0.902	0.886	0.005				*	*
Digestible energy (MJ/kg)	14.3	14.5	14.2	14.4	14.1	0.93				*	

[1]See footnote to Table 2 for definitions.
[2]C1 = difference between control and (LR + HR)/2; C2 = difference between control and (LG + HG)/2; C3 = difference between LG + HG and LR + HR; C4 = difference between LR and HR; C5 = difference between LG and HG.

Table 6. Effect of dietary treatment on the sensory properties of cooked porcine muscle

Comparison	Number of panellists	Number of samples correctly identified	P value
Control *v.* LR[1]	26	10	
Control *v.* HR[1]	25	9	
Control *v.* LG[1]	26	12	
Control *v.* HG[1]	26	17	***

[1]See footnote to Table 2 for definitions.

nutrients in the intestinal lumen, as well as altering intestinal morphology and the capacity of the gut to absorb nutrients (De Lange, 2000). Secondly, at high inclusion levels, it is possible that the antimicrobial action of allicin (Ankri and Mirelman, 1999) may be sufficient to inhibit microbial fermentation, thus reducing total tract nutrient digestibility.

The inclusion of garlic in the diet at 1 g/kg and 10 g/kg decreased feed intake by 5% and 7%, respectively, during the grower-finisher period compared to the control. This reduction was particularly evident during the grower period, with a 9% and 12% reduction in feed intake for the 1 g/kg and 10 g/kg garlic diets, respectively. Similar reductions in feed intake have been reported by others (Grela, Krusinski and Matras, 1998; Holden, McKean and Franzenburg, 2001; Holden and McKean, 2002). In contrast, Corrigan *et al.* (2001) found that garlic in the diet of nursery pigs increased feed intake; however, garlic was used in association with a blend of plant extracts, mixed herbs and essential oils and therefore it is possible that the other herbs and plant extracts may have masked the strong odour of garlic. This suggests that it is the organoleptic properties of garlic that are responsible for the decreased feed indicate. The sense of taste is an important factor in determining the selection of food by animals (Baldwin, 1976) while the importance of olfaction is also recognised (Forbes, 1995). This is of particular importance to the pig as its sense of smell is heavily implicated in feed intake (Mellor, 2000). Allicin is an extremely odoriferous compound (Cavallito and Bailey, 1944). It is worth noting that in the present study, the decrease in feed intake was not significant during the finisher period implying that the pig may become accustomed to garlic.

Despite a reduction in feed intake and digestible energy intake associated with garlic inclusion, there was no negative effect of garlic on live-weight gain. The inclusion of garlic in the diet at 1 g/kg improved FCR by 9.8% during the grower period and 5.7% during the combined grower-finisher period while the inclusion of garlic at 10 g/kg improved FCR by 7.0% during the grower period and 6.5% during the combined grower-finisher period compared to the control diet. The improvement in FCR reported in the present study is greater than the improvement in FCR noted in previous studies using antibiotics as growth promoters. Zimmerman (1986) reported an improved FCR of 4.5% and 2.2% in grower (17 to 49 kg) and grower-finisher pigs (24 to 89 kg), respectively, when antibiotics were included in the diet.

The improvement in feed efficiency may have a number of explanations. Firstly, the inclusion of garlic in the diet may result in an improved gut environment and microflora. This effect is attributed to the fact that the susceptibility of pathogenic gram-positive bacteria to the antibacterial components of garlic is higher than that of the physiologically desirable intestinal bacteria (Rees *et al.,* 1993). The beneficial bacteria are believed to be unaffected by the presence of garlic as they are less sensitive to its inhibitory effects. Furthermore, garlic may have a prebiotic effect due to its classification as a fructooligosaccharide (Gibson, 2001).

Secondly, the improvement in feed efficiency with the inclusion of garlic may be attributed to the lower DE intake of pigs offered the garlic diets compared to those offered the control diet. The FCR in finishing pigs improves with increasing energy intake up to 33 MJ DE/day but deteriorates with each increase in DE intake thereafter (Campbell, Taverner and Curic, 1985). Similar trends in FCR were reported by O'Doherty and McKeon (2000) when using similar genotypes as in the current experiment. In the current study the DE intake of pigs on all diets was greater than 33 MJ/day and as the pigs on the HG diet had the lowest DE intake (34.5 MJ/day) it is not unexpected that HG produced the best FCR.

Thirdly, at high inclusion levels of garlic it is possible that the antimicrobial action of allicin (Ankri and Mirelman, 1999) may be sufficient to inhibit microbial fermentation. In rapidly growing young animals, the gastro-intestinal tract and the skeletal musculature draw from the same limited supply of nutrients and are in effect competitors for the deposition of nutrients (Reeds *et al.,* 1993). As much as 6% of the net energy in pig diets can be lost due to bacterial utilisation of glucose in the small intestine (Vervaeke *et al.,* 1979) and these bacteria require amino acids in relatively similar proportional amounts as the pig (Hays, 1978). When garlic was added at 10 g/kg there may have been a nutrient sparing effect, therefore improving FCR.

There is a lot of inconsistency in the literature concerning the performance of pigs offered diets containing garlic (Grela *et al.,* 1998; Holden *et al.,* 2001; Holden and McKean, 2002; Corrigan *et al.,* 2001). This inconsistency may be due to variable inclusion levels of garlic and in the allicin and alliin concentrations of the garlic used.

The results of the sensory analysis support the contention that some garlic components of dietary origin are deposited in muscle but further studies are needed to establish the identity of these components.

While the inclusion of rosemary had no beneficial effects on growth performance or carcass characteristics the results show that the use of garlic in the diet of grower-finisher pigs has the potential to improve the performance of grower-finisher pigs in a growth-promoter free environment. Sensory evaluation showed that only pork from pigs fed the high level of garlic diet could be differentiated from control pork. However, further research is required to examine the effect of herbs in diets on meat quality.

References

AOAC (Association of Official Analytical Chemists). 1980. 'Official Methods of Analysis' (13th edition), Association of Official Analytical Chemists, Washington DC, USA.

Ankri, S. and Mirelman, D. 1999. Antimicrobial properties of allicin from garlic. *Microbes and Infection* **2:** 125–129.

Arnault, I., Christides, J.P., Mandon, N., Haffner, T., Kahane, R. and Auger, J. 2003. High-performance ion-pair chromatography method for simultaneous analysis of alliin, deoxyalliin, allicin and dipeptide precursors in garlic products using multiple mass spectrometry and UV detection. *Journal of Chromatography* **991:** 69–75.

Ashgar, A., Lin, C.F., Gray, J.I., Buckley, D.J., Boore, A.M., Crackel, R. and Flegal, C.J. 1989. Influence of oxidised dietary oil and antioxidant supplementation on membrane-bound lipid stability in broiler meat. *British Poultry Science* **18:** 59–68.

Baldwin, B.A. 1976. Quantitative studies on taste preference in pigs. *Proceedings of the Nutrition Society* **35:** 69–73.

Campbell, R.G., Taverner, M.R. and Curic, D.M. 1985. Effects of sex and energy intake between 48 and 90 kg live weight on protein deposition in growing pigs. *Animal Production* **40:** 497–503.

Cavallito, C.J. and Bailey, J.H. 1944. Allicin, the antibacterial principle of *Allium sativum*. Isolation, physical properties and antibacterial action. *Journal of the American Chemical Society* **66:** 1950–1951.

Close, W.H. 2000. Producing pigs without antibiotic growth promoters. In: 'Advances in Pork Production', Volume 11, University of Alberta, Department of Agriculture, Food and Nutritional Science, pages 47–56.

Corrigan, B.P., Wolter, B.F., Ellis, M. and Moreland, S. 2001. Effect of three dietary growth promoting additives on performance of nursery pigs. *Journal of Animal Science* 79 (Suppl.1): 1885 (Abstract).

Cuvelier, M., Richard, H. and Berset, C. 1996. Antioxidative activity and phenolic composition of pilot-plant and commercial extracts of sage and rosemary. *Journal of the American Oil Chemists Society* **73:** 645–652.

De Lange, C.F.M. 2000. Characterisation of the nonstarch polysaccharides. In: 'Feed Evaluation, Principles and Practice' (ed. P.J. Moughan, M.W.A. Verstegen and M.I. Visser-Reyneveld), Wageningen Pers, Wageningen, The Netherlands, pages 77–92.

Department of Agriculture and Food, Ireland. 1994. Pig Carcass Dressing Specification. SI 216.

Farag, R.S., Badei, A.Z.M.A., Hewedi, F.M. and Elbaroty, G.S.A. 1989. Antioxidant activity of some spice essential oils on linoleic-acid oxidation in aqueous media. *Journal of the American Oil Chemists Society* **66:** 792–799.

Fernandez, J.A. and Jorgenson, J.M. 1986. Digestibility and absorption of nutrients as affected by fibre content in the diet of the pig. *Livestock Production Science* **15:** 53–71.

Forbes, J.M. 1995. Learning about food preferences. In: 'Voluntary Food Intake and Selection in Farm Animals', CAB International, Oxon, UK, pages 247–276.

Gibson, G.R. 2001. Prebiotics for improved gut health. *Food Science and Technology Abstracts,* Abstract 3731.

Griffiths, D.W. and Moseley, G. 1980. The effect of diets containing field beans of high or low polyphenolic content on the activity of digestive enzymes in the intestines of rats. *Journal of the Science of Food and Agriculture* **31:** 255–259.

Grela, E.R., Krusinski, R. and Matras, J. 1998. Efficacy of diets with antibiotic and herb mixture additives in feeding of growing-finishing pigs. *Journal of Animal and Feed Sciences* **7:** 171–175.

Hays, V.W. 1978. The role of antibiotics in efficient livestock production. In: 'Nutrition and Drug Interrelations', Academic Press, New York, pages 545–575.

Holden, P.J., McKean, J.D. and Franzenburg, E. 2001. Botanicals as part of an integrated value-added pork production system. Leopold Center Progress Report, Volume 10, Iowa State University, USA.

Holden, P.J. and McKean, J.D. 2002. Botanicals for nursery pigs. *Journal of Animal Science* **80** (Supplement 1): **41** (Abstract).

Horton, G.M.J., Blethen, D.B. and Prasad, B.M. 1991. The effect of garlic (*Allium sativum*) on feed palatability of horses and feed consumption, selected performance and blood parameters in sheep and swine. *Canadian Journal of Animal Science* **71:** 607–610.

Inatani, R., Nakatani, N. and Fuwa, H. 1983. Antioxidative effect of the constituents of rosemary (*Rosmarinus officinalis* L.) and their derivatives. *Agricultural and Biological Chemistry* **47:** 521–528.

Jansman, A.J.M. 1993. Tannins in feedstuffs for simple-stomached animals. *Nutrition Research Reviews* **6:** 209–236.

Jost, M. 1996. Einsatz von Knoblauchpulver im Ferkelaufzuchtfutter. *Agrarforschung* **3** (10): 479–481.

Lin, C.F., Gray, J.I., Ashgar, A., Buckley, D.J., Booren, A.M. and Flegal, C.F. 1989. Effects of dietary oils and (α-tocopherol supplementation on lipid composition and stability of broiler meat. *Journal of Food Science* **54:** 1457–1460.

Liu, H.F., Booren, A.M., Gray, J.I. and Crackel, R.L. 1992. Antioxidant efficacy of oleoresin rosemary and sodium tripolyphosphate in restructured pork steaks. *Journal of Food Science* **57:** 803–806.

McDonald, B. and Wood, C.M. 2002. Feed additives in swine diets. In: 'Virginia State University Livestock Update' (January 2002), Published by Virginia State University, USA.

Meilgaard, M., Civilla, G.V. and Carr, B.T. 1999. 'Sensory Evaluation Techniques' (3rd edition), CRC Press.

Mellor, S. 2000. Herbs and spices promote health and growth. *Pig Progress* **16:** 27–30.

O'Doherty, J.V. and McKeon, M.P. 2000. The use of expeller copra meal in grower and finisher pig diets. *Livestock Production Science* **67:** 55–65.

Reeds, P.J., Burrin, D.G., Davis, T.A. and Fiorotto, M.L. 1993. Post-natal growth of gut and muscle: competitors or collaborators. *Proceedings of the Nutrition Society* **52:** 57–67.

Rees, L.P., Minney, S.F., Plummer, N.T., Slater, J.H. and Skyrme, D.A. 1993. A quantitative assessment of the antimicrobial activity of garlic (*Allium sativum*). *World Journal of Microbiology and Biotechnology* **9:** 303–307.

R & H Hall Technical Bulletin. 1996. Feed Tables, Issue 5, pages 1–8.

SAS. 1985. Statistical Analysis Systems. SAS Institute Inc., Cary, NC, USA.

Small, L.D., Bailey, J.H. and Cavallito, C.J. 1947. Alkyl thiosulphinates. *Journal of the American Chemical Society* **69:** 1710–1713.

Tsai, Y., Cole, L.L., Davis, L.E., Lockwood, S.J., Simmons, V. and Wild, G.C. 1985. Antiviral properties of garlic: *in vitro* effects on Influenza B, Herpes simplex and Coxsackie viruses. *Planta Medica* **5:** 460–461.

Van Soest, P.J., Robertson, J.B. and Lewis, B.A. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* **74:** 3583–3597.

Vervaeke, I.J., Decuypere, J.A., Dierick, N.A. and Henderickx, H.K. 1979. Quantitative *in-vitro* evaluation of the energy metabolism influenced by Virginiamicin and Spiramyin used as growth promoters in pig nutrition. *Journal of Animal Science* **49:** 846–856.

Wenk, C. 2000. Herbs, spices and botanicals: 'Old fashioned' or the new feed additives for tomorrow's feed formulations? Concepts for their successful use. In: 'Biotechnology of the Feed Industry'. *Proceedings of Alltech 16th* Annual Symposium (ed. T.P. Lyons and K.A. Jacques), pages 79–96.

Williams, C.H., David, D.J. and Iismaa, O. 1962. The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. *Journal of Agricultural Science* **59:** 381–385.

Yu, F., Moughan, P.J., Barry, T.N. and McNab, W.C. 1996. The effect of condensed tannins from heated and unheated cottonseed on the ileal digestibility of amino acids for the growing rat and pig. *British Journal of Nutrition* **76:** 359–371.

Ziegler, S.J. and Sticher, O. 1989. HPLC of S-alk(en)yl-L-cysteine derivatives in garlic including quantitative determination of (+)-S-allyl-L-cysteine sulfoxide (Alliin). *Planta Medica* **55:** 372–378.

Zimmerman, D.R. 1986. Role of subtherapeutic antimicrobials in animal production. *Journal of Animal Science* **62:** (Suppl. 3): 6.

Received 23 July 2004